Switching of Magnetic Films by Femtosecond Laser Pulses and Control Spin Current

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Abstract

Spintronic belongs to one of the most the quickly developing area of science and technology, which is based on the control over the processes of transfer of spin current among the elements of electronic devices. To create high-spintronics, elements necessary reversing control the magnetic electrodes with high speed. Interestingly, the possibility of the magnetization control in heterogeneous magnetic nanostructures can be realized by picosecond and femtosecond laser pulses. Such short laser pulses allow geting a large spin current along a laser beam and inducing the effective internal magnetic field of the inverse magnetooptical Faraday effect provides ultra-speed magnetic switching in the magnetic nanostructures. This article presents the results of experimental studies of the dynamics of magnetization reversal by femtosecond laser pulses of a magnetic nanofilms with one or two the magnetic nanolayers and shows that by using ultrashort laser pulses, it is possible not only to study the dynamics and transport processes of the spin current in multilayer magnetic nanofilms, but also to control the spin transport in the spintronic elements.

Keywords

Spintronic; Femtosecond Laser Pulses; Magnetic Reversal of Nanofilms; Control a Spin Current

Introduction

Studies of laser interaction with material have opened several new physical issues, such as laser-induced orientation of electron spins [Lampel, 1968], photon pressure, or photon drag effect in solids [Danishevskii et al, 1970 and Gibson et al, 1970], the drift of particles under laser irradiation [Ashkin, 1972], cooling of atoms in laser field [Phillips, 1998], and laser-induced drift of atoms in the gas mixture [Gelmuhanov et al, 1979], as well as the dynamics of many high-speed processes in solids. The most interesting results in this direction obtained by using femtosecond laser pulses can be attributed to the results of the magnetization reversal of magnetic nanofilms by femtosecond laser pulses [Stanciu et al, 2007 and Ostler et al 2012]. Magnetic nanofilm structures are the basic material for spintronics elements and recording medium. Spintronics is based on the transport processes of spin-polarized current among the elements of electronic devices. Study on the dynamics of the spin relaxation processes in solids and development of methods for active control of spin spin-polarized current in solid-state circuits constitutes the main direction of the spintronics. For spin current control in spintronics devices, it is necessary to change the state of magnetization of spin filter elements. Determination of maximum speed reversal is one of the fundamental problems of the physics of magnetism, which is of great importance in the development of high-speed spintronic elements and systems magnetic recording media.

This article presents the results of experimental studies on the dynamics of magnetization reversal by femtosecond laser pulses of a magnetic nanofilms with one or two the magnetic nanolayers and shows that by using ultrashort laser pulses, it is possible to not only study the dynamics and transport processes of the spin current in multilayer magnetic nanofilms, but also control the spin transport in the spintronic elements. It is hoped that these results will be useful in studying the spin-dependent processes in magnetic materials, as well as the development of new high-speed spintronic elements..

Mechanisms of Magnetic Switching of Magnetic Films by Laser Radiation

Before turning to the results of experimental studies of the dynamics of magnetic reversal nanofilms femtosecond laser pulses, a possible mechanisms of this reversal is taken into account. Magnetic reversal magnetic nanolayers at its irradiation laser pulses can be caused by thermal as well as non thermal influence of this radiation. The thermal component of this impact is exhibited via the temperature dependence of the magnetization and magnetic anisotropy constants that lead to the change of spin states of the system. Heating of a single-layer magnetic nanofilm with non-

absorptive protective layer and substrate exposed to femtosecond and picosecond pulses can be estimated in the first approximation as

$$\Delta T < \frac{(1-R)[1-exp(-\alpha h_m)]I_0\tau_i}{c_m\rho_m h_m + 2c_1\rho_1\sqrt{K_1\tau_i}}, \quad (1)$$

where I_0 and τ_i are the radiation intensity and duration of a laser pulse, respectively; α and R are the coefficients of absorption and reflection of laser radiation for a magnetic layer, respectively; h_m is the thicknesses of the magnetic layers; c_m, c_1, ρ_m, ρ_1 are the specific heats and densities of the magnetic layer and substrate, respectively; K_1 is the thermal diffusivities of the substrate. Using typical values for the parameters results in higher: $\alpha=10^5\ cm^{-1}$, $R=0,5$, $h_m=20\ nm$, $c_m=0.5\ J/(g\ K)$, $c_1=1,1\ J/(g\ K)$, $c_1=1,0\ J/(g\ K)$, $\rho_m=7,9\ g/cm^3$, $\rho_1=4,0\ g/cm^3$, $K_1=0,006\ cm^2/s$, we will get $\Delta T\sim10°$ for the femtosecond pulse of duration $\tau_i=100\ fs$ and intensity $I_0=10^{10}W/cm^2$.

In the case of thermal action, laser heating of nanolayers considerably reduces their coercive force. When the coercive force of a magnetic nanolayer becomes smaller than the oppositely directed external magnetic field H_0, reversal magnetization takes place in this layer. Such a mechanism of magnetic reversal is well-known and also is widely used for magneto-optical recording [Leamy et al, 1979 and Komori et al, 1984] in ferrimagnetic films in which strong dependence coercive force from temperature is observed.

Recently, data has been obtained on a high-speed thermal magnetization of a ferrimagnetic layers (alloys of rare-earth and transition metal) with the antiferromagnetic interaction [Stanciu et al, 2006]. Such a reversal may take place without external magnetic field. High speed laser-induced magnetization reversal associated with the processes of thermal demagnetization sublattice ferrimagnetic material has the opposite magnetization orientation. Laser-induced thermal demagnetization of each magnetic sublattice is due to their antiferromagnetic exchange interaction. Total magnetization of the ferromagnetic depending on the magnetic structure can pass through the point of compensation (when the total magnetic moment of the magnet is zero) [Stanciu et al, 2007], or through an intermediate magnetic state in which the magnetization of the sublattices has the same direction. This magnetic state occurs due to difference in the rate of the thermal demagnetization of the magnetic sublattices of the rare-earth and transition metal [Radu et al, 2011]. Further magnetic reversal of a magnetic film occurs under the influence of an effective internal field of antiferromagnetic interaction between magnetic sublattices rare-earth and transitive metals [Radu et al, 2012].

However, it should be noted that in ferromagnetic films with perpendicular anisotropy, the magnetization reversal process heat is important field demagnetization Hdm emerging in the region of action of laser radiation. The demagnetizing field in the region of diameter d0 and thickness h of a magnetic nanolayer heated to the Curie temperature can be estimated using the expression

$$H_{dm} \approx \frac{h}{d_0} H_a \ , \quad (2)$$

where H_a is the coercive force of the magnetic nanolayer.

In non thermomagnetic mechanism of magnetic reversal of the magnet, nanolayers may cause their direct reversal in the magnetic field generated by laser radiation due to the inverse Faraday effect [Pershan et al, 1966, Hertel, 2006 and Kimel et al, 2009]. Such a mechanism generates a magnetic field only when are the circular polarization of laser radiation and a magnetic field proportional to the square of the field intensity $\vec{E}$ of the light wave. The circular polarization of laser radiation is due to this effect in the medium, a nonequilibrium magnetization $\vec{M}_F$ is directed along the propagation of the laser beam $\vec{M}_F = \chi\left[\vec{E}\times\vec{E}^*\right]/16\pi$,

and χ is the magneto-optical susceptibility of the medium. In thin conducting magnetic films, the value of the magnetization induced by circularly polarized light wave can be estimated on the basis of a circular current induced by laser radiation [Hertel, 2006]. For the magnetic field H_F in the conductive magnetic film with a magnetic permeability μ circularly polarized laser light with the intensity of the radiation I, we obtain the following formula:

$$\vec{M}_F = \frac{ie^3N}{4(m_e^*)^2\omega^3}\left[\vec{E}\times\vec{E}^*\right],$$

$$H_F = \frac{\left|\vec{M}_F\right|\mu}{4\pi\mu_0} = \frac{e^3\mu NE^2}{16\pi\mu_0 n(m_e^*)^2\omega^3} = \frac{e^3\mu NI}{8\pi\mu_0 c\varepsilon_0 n(m_e^*)^2\omega^3} \quad (3)$$

Where N is the average concentration of conductive electrons; ε and μ is dielectric and magnetic film permeability. The mentioned laser-induced internal magnetic field can reach large values $H_F>10^5$–10^6 A/m for magnetic films with the magnetic permeability $\mu=10^3$-10^4 under relatively low radiation intensity of picosecond pulses $I=10^9$ W/cm^2 at the average concentration of conductive electrons $N\approx10^{22}$ cm^{-3}. The

characteristic relaxation time for the inverse nonlinear Faraday effect ranges from 10^{-13} to 10^{-14} s. The direction of the magnetization vector varies with the direction of rotation of the field vector of circularly polarized electromagnetic radiation on the opposite. Therefore, by using laser radiation with the right circular polarization or the left circular polarization, the magnetic field directed towards the laser beam or against it can be obtained .

In multilayer magnetic structures, a significant contribution to the variation in magneto-optical characteristics of the second and next magnetic nanolayers is made by a new physical mechanism of magnetic switching [Slonczewski, 1996, and Katine et al, 2000]. That mechanism is related to a laser-induced spin current because of a photon pressure. The laser-induced injection of spin-polarized electron from the first magnetic layer produces a nonequilibrium magnetic field H_i in the next layer $\overrightarrow{H_i} = \overrightarrow{H_e} + \overrightarrow{H_s}$. This field consists of the self-field H_e of the electric current and magnetic field H_s related to the total magnetic moment of the injection spins $S = \gamma \sum_i s_i$. These magnetic fields have different directions: the field produced by electric current H_e lies in the plane of the film, while the field of the total spin moment of the electrons injected from the first magnetic layer H_s is directed along the magnetization $\overrightarrow{M}_1$ of the first magnetic layer. In case of perpendicular anisotropy, the first magnetic layer H_s is directed normally to the second magnetic layer. The results of the article [Slonczewski, 1996] have shown the relation $H_e / H_s \sim d_0$ (d_0 is the diameter of the current conductor). To estimate the magnitude of the magnetic field H_e and H_s , we will use the following expression for the density of injection current $j_s = -e\alpha(1-R)In_0\tau_p\eta\xi / m_e c$ emerging under the action of photon pressure of laser radiation [Askaryan et al, 1967, and Krupa et al, 2007]. Since the laser pulse duration τ_l is larger or comparable with the pulse τ_p and the spin relaxation time τ_s in the magnetic nanolayer, the internal magnetic field H_s and H_e can be described by the estimating expression.

$$H_s = l_s\alpha(1-R)I\mu_B\mu\frac{n_0\tau_p\tau_s\gamma\eta\xi}{2\mu_0 h_2 m_e c}$$

$$H_e = l_e\alpha(1-R)Ier\frac{n_0\tau_p\gamma\xi}{4\pi m_e c} \qquad (4)$$

where I, α and R as well as n_0 are an intensity, absorption and reflection coefficients, and also refractive index of laser radiation falling on the first magnetic layer, respectively; r is the radius of a laser beam, h_1 and m_e are the thickness of the first magnetic nanolayer and effective electron mass; c is a light speed; $\gamma<1$, $\eta<1$ and $\xi<1$ are coefficients characterizing a momentum transfer from photons to electrons in the first magnetic layer and the degree of an electron polarization and affectivity of the electron passage from the first into the second nanolayer; μ_B is the Bohr magneton; μ and μ_0 are the a magnetic and absolute magnetic permeability; l_s and l_e are proportionality constant. The value of the magnetic field will be estimated, created in the second magnetic nanolaer due to the injection of the polarized electrons. At $I=10^9 W/cm^2$, $\alpha=10^5\ cm^{-1}$, $R=0{,}5$, $r=10^{-6}\ m$, $\tau_s=10^{-10}$-$10^{-11}\ s$, $\tau_p=10^{-11}$-$10^{-12}\ s$, $\mu=10^4$, $\gamma=0{,}8$, $\eta=0{,}8$, $\xi=0{,}5$, the value $H_s>10^7\ A/m$ and $H_e=10^5$-$10^5\ A/m$ can be acquired. Thus theoretical estimates have shown that the laser-induced spin-polarized current can cause the magnetic switching of magnetic layers with perpendicular and planar uniaxial magnetic anisotropy.

Generally, because of absorption of laser radiation and heating magnetic layer, the value of magnetic moment $\overrightarrow{M}$ in the area of irradiation will change, and the dynamics of variation of magnetization in a magnetic nanolayer can be described with the help of the Landau–Lifshitz-Gilbert equation of the form

$$\frac{d\overrightarrow{M}}{dt} = -\gamma\left[\overrightarrow{M} \times \overrightarrow{H}_{eff}\right] + \frac{k}{M}\left[\overrightarrow{M} \times \frac{\partial\overrightarrow{M}}{\partial t}\right] \qquad (5)$$

Here γ is the gyromagnetic ratio, $k\cdot$ is the dimensionless damping constant, though $0<k<1$, t is a time. The effective magnetic field can be represented as the sum $\overrightarrow{H}_{eff} = \overrightarrow{H}_{ext} + \overrightarrow{H}_{an} + \overrightarrow{H}_F + \overrightarrow{H}_i + \overrightarrow{H}_{dm}$ where H_{ext} consists of external magnetic field, H_{an} is coercive force of the magnetic layer, H_F is magnetic field produced by circularly polarized laser radiation owing to the inverse Faraday effect, $\overrightarrow{H_i} = \overrightarrow{H_e} + \overrightarrow{H_s}$ is magnetic field of the laser-injected spin-polarized electron current and H_{dm} is effective demagnetizing field. The equilibrium magnetic orientation corresponds to the condition $dM/dt=0$.

It follows from formula (5) that the sign reversal of the effective magnetic field at the instant of action of laser pulses may change the direction of the magnetization vector $\overrightarrow{M}$ in the irradiated magnetic nanolayer owing to any of the mechanisms described above. The reason for such magnetization reversal may be thermal heating in an external magnetic field or demagnetizing field, the magnetic field induced by circularly polarized laser

radiation owing to the inverse magnetooptical Faraday effect, and the magnetic field of spin current produced in the second magnetic layer by polarized electrons injected from the first magnetic layer. Such a spin current emerges under the effect of photon pressure of laser radiation. Through variation of the experimental conditions, it is possible to make any of these mechanisms predominant and use it for information recording as well as for developing high-speed optoelectronic switches and other spintronics devices.

Experimental Technique and Measured Results

In the present paper, we have studied magnetic switching dynamics of magnetic nanolayers in the film

$Al_2O_3/Tb_{25}Co_5Fe_{70}/Al_2O_3$, $Al_2O_3/Tb_{22}Co_5Fe_{73}/Al_2O_3$, $Al_2O_3/Tb_{19}Co_5Fe_{76}/Al_2O_3$, $Al_2O_3/Co_{30}Fe_{70}/Al_2O_3$

with a single magnetic nanolayer and the films

$Al_2O_3/Tb_{22}Co_5Fe_{73}/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}/Al_2O_3$, $Al_2O_3/Co_{80}Fe_{20}/Pr_6O_{11}/Co_{30}Fe_{70}/Al_2O_3$

with two magnetic nanolayers radiated by femtosecond ($\tau_i \approx 130\ fs$) laser pulses. Besides, the influence of the laser pulse on the conductivity of the tunnel microcontacts has been investigated as well: $Tb_{22}Co_5Fe_{73}/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}$, $Co_{80}Fe_{20}/Pr_6O_{11}/Co_{30}Fe_{70}$. The films are sprayed by a magnetron deposition technique on plates with sizes *10x14mm* and discs with the diameter *110mm* from optical fused quartz with the thickness *1,2mm*. Thicknesses of magnetic nanolayers TbCoFe and CoFe constituted *20 nm*. For the barrier nanolayer Pr_6O_{11} and the cover layer Al_2O_3 that thickness constitutes *2-3nm* and *40nm*, respectively. The tunnel microcontacts with a conductive surface $S \approx 20\mu^2$ are produced by a photolithography technique on the plates with sizes *10x14mm*. The edge of plates through which the current is inputted to the tunnel contacts TbCoFe and CoFe is covered by platinum. The contact zone and conductive magnetic strips are also protected by the Al_2O_3 cover with thickness near 40*nm*. Before measurements, Testing of microcontacts with large and near tunnel resistances has been carried out.

Amorphous ferrimagnetic films of alloys of transition and rare-earth metals may operate as effective spin-current injectors with magnetic parameters that can be controlled by ultrashort laser pulses. The high energy of the perpendicular anisotropy and considerable coercive force [Leamy et al, 1979 and Komori et al, 1984] ensure a long lifetime for the magnetization state in such materials, which is close to saturation magnetization even in the zero external magnetic field. It should result in the high degree of an electron polarization. The strong temperature dependence of the coercive force and the low Curie temperature (near 300 K) make it possible not only to use such films for optical information recording, but also to develop optoelectronic microelements of spintronics on the basis of these films.

The ferrimagnetic films $Tb_{22}Co_5Fe_{73}$ and $Tb_{19}Co_5Fe_{76}$ have a composition which is close the composition in compensation point $Tb_{22}Fe_{78}$ that provides high energy of the perpendicular anisotropy. A small distinction in composition (cobalt addition reduces egging and, virtually, does not influence magnetic characteristics of the layers) results in a constitutive difference in coercive force values [Krupa et al, 2001]. At $T=300\ K$ the coercive forces of the layers $Tb_{22}Co_5Fe_{73}$ and $Tb_{19}Co_5Fe_{76}$ constitutes $H_1 \approx 3x10^5 A/m$ and $H_2 \approx 1,2x10^5 A/m$, respectively (Fig. 1). In these ferromagnetic films of iron and terbium sublattice are magnetized by the antiferromagnetic interaction towards each other. In films $Tb_{22}Co_5Fe_{73}$ and $Tb_{19}Co_5Fe_{76}$ the total magnetic moment is directed toward the sublattice magnetization of iron, and in the film $Tb_{25}Co_5Fe_{70}$, it is directed in the direction of magnetization of the terbium sublattice. It is known that the magnitude of the effects of Kerr and Faraday in these films are determined by the interaction with the iron sublattice. Therefore, the plane of polarization is rotated by the action of the Kerr and Faraday effects in the film $Tb_{25}Co_5Fe_{70}$ in the opposite direction compared to films $Tb_{22}Co_5Fe_{73}$ and $Tb_{19}Co_5Fe_{76}$ even if its parallel magnetization. The ferromagnetic films CoFe in the magnetized state also have a high degree of electron polarization [Chen et al, 2006]. In ours samples, the substrate at film deposition of the nanolayers $Co_{30}Fe_{70}$ and $Co_{80}Fe_{20}$ was under the external magnetostatic field that provides production of the films with a small angular dispersion($\Delta\alpha \approx 3^0$) of planar single-axis magnetic anisotropy. The coercive force of the ferromagnetic nanolayers $Co_{30}Fe_{70}$ and $Co_{80}Fe_{20}$ differs appreciably because of distinctions of compositions in $Co_{30}Fe_{70}$ ($H'_1 \approx 300A/m$) and $Co_{80}Fe_{.20}$ ($H'_2 \approx 800A/m$)(Fig. 1). As a result, we obtaind the tunnel microcontact $Co_{80}Fe_{20}/Pr_6O_{11}/Co_{30}Fe_{70}$ with a small dispersion of magnetization axis, which allowed a magnetic switching of low coercive nanolayers $Tb_{19}Co_5Fe_{76}$ and $Co_{30}Fe_{70}$ by the external magnetic field without changing the magnetization direction of high coercive nanolayers $Tb_{22}Co_5Fe_{73}$ and $Co_{80}Fe_{20}$. Magnetic field direction coincided with an easy magnetization axis and its value varied from *0* to $8x10^5\ A/m$.

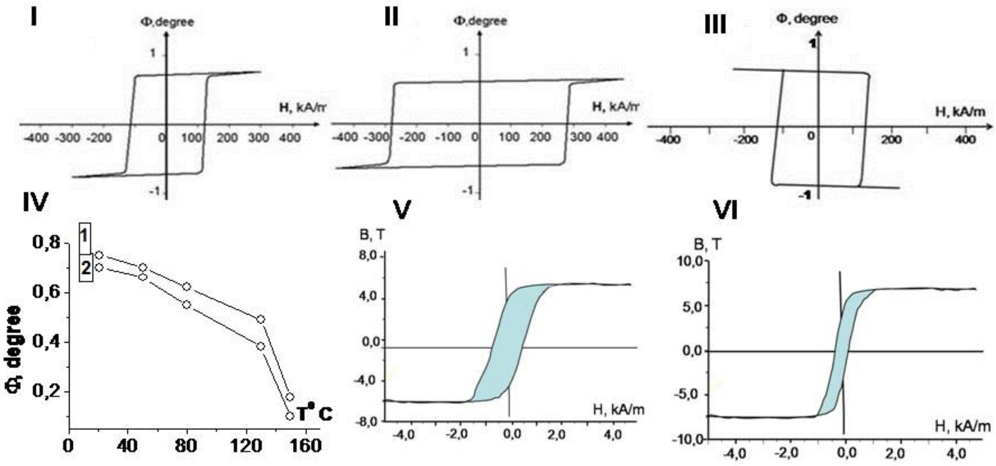

FIG. 1 THE CURVES OF CHANGE OF THE KERR ANGLE (Φ) IN NANOLAYERS $TB_{19}CO_5FE_{76}$ (I, IV-1), $TB_{22}CO_5FE_{73}$ (II, IV-2) AND $TB_{25}CO_5FE_{70}$ AND THE B-H CURVES OF NANOLAYERS $CO_{80}FE_{20}$ (V) AND $CO_{30}FE_{70}$(VI)

As a result, we obtaind the tunnel microcontact $Co_{80}Fe_{20}/Pr_6O_{11}/Co_{30}Fe_{70}$ with a small dispersion of magnetization axis, which allowed a magnetic switching of low coercive nanolayers $Tb_{19}Co_5Fe_{76}$ and $Co_{30}Fe_{70}$ by the external magnetic field without changing the magnetization direction of high coercive nanolayers $Tb_{22}Co_5Fe_{73}$ and $Co_{80}Fe_{20}$. Magnetic field direction coincided with an easy magnetization axis and its value varied from *0* to *8x10⁵ A/m*.

The magnetic switching dynamics of the magnetic nanolayers in the films has been studied with the help of the magnetooptical Kerr and Faraday effects on a polarization twisting of laser radiation. The scheme of corresponding optical research is represented in Fig 2.

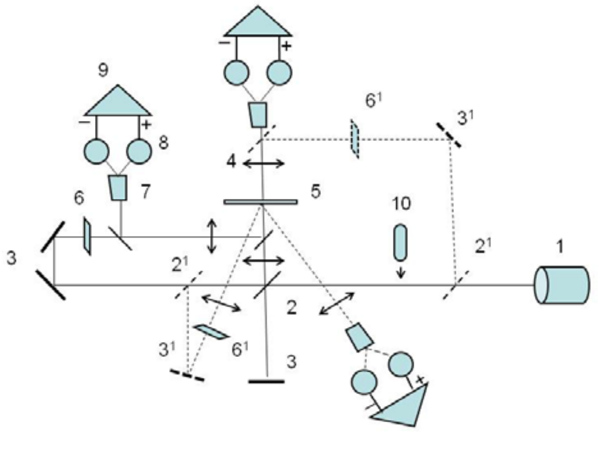

FIG. 2 EXPERIMENTAL SCHEME OF THE OPTICAL INVESTIGATION: FEMTOSECOND LASER –1, 50% MIRROR –2, TOTAL REFLECTION MIRROR –3, LONG-FOCUS LENS –4, SUBSTRATE WITH FILM –5, POLARIZER –6, SENARMON PRISM –7, PHOTODIODE –8, DIFFERENTIAL AMPLIFIER –9, BABINET COMPENSATOR –10

The femtosecond pulse (*τᵢ≈130 fs*) of the laser 1 was split mirror 2 to the exciting and probe pulses. The excitation laser pulse reflected from the mirror 3 and focused on the long-focus lens 4 of the film on the substrate 5. The probe laser pulse is passed through a delay line, polarizer 6 and focused by a lens in the same area of the film. Using mirrors 2^1, 3^1 and a polarizer 6^1, we can direct this probe laser pulse in the same area of the film or at an oblique angle or from the opposite side of the film. The reflected radiation probe laser pulse was divided into two beams by the polarization Senarmont prism 7 and registered by reading photodiode 8. The electric signals from the reading photodiode are amplified by the differential amplifiers 9. Then these signals are registered by the double-beam oscilloscope. For the research of the magnetic switching by circularly polarized laser pulses, we introduced the Babinet compensator 10 into the system. The rotation of the laser radiation polarization plane upon reflection or transmission was measured with the help of the differential signal from photodiodes 9.

The time resolution of the electrical system of registration was less than 1 ns. The delay time curve of the probe linearly polarized laser pulse allows us to study the dynamics of changes in the angles Kerr or Faraday in our films up to 5 picoseconds. Measurements with a probe laser pulse, we averaged the data obtained for 20 cycles of the measurement, thus increasing the accuracy of our measurements.

In studies of nanofilms

$Al_2O_3/Tb_{25}Co_5Fe_{70}/Al_2O_3$,$Al_2O_3/Tb_{19}Co_5Fe_{76}/Al_2O_3$,and $Al_2O_3/Tb_{22}Co_5Fe_{73}/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}/Al_2O_3$,

with perpendicular anisotropy, we used the measurement scheme Faraday angle or the angle of the polar Kerr effect. In studies of nanofilms

$Al_2O_3/Co_{30}Fe_{70}/Al_2O_3$ and $Al_2O_3/Co_{80}Fe_{20}/Pr_6O_{11}/Co_{30}Fe_{70}/Al_2O_3$ with uniaxial anisotropy in the plane, we used the

scheme of measurements of the angle of the equatorial Kerr angle. In our studies, the effect of the femtosecond laser pulses on the change in conductivity of microcontact

$Tb_{22}Co_5Fe_{73}/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}$ and
$Co_{80}Fe_{20}/Pr_6O_{11}/Co_{30}Fe_{70}$

has also been investigated. The magnetic electrodes of microcontact magnetized by an external magnetic field in one direction or towards one another, and then irradiated with femtosecond laser pulses were irradiated with the magnetic nanolayer $Tb_{22}Co_5Fe_{73}$ and $Co_{80}Fe_{20}$ with high coercive force, or by a nanolayer $Tb_{19}Co_5Fe_{76}$ and $Co_{30}Fe_{70}$ with low coercive force.

The results of our research have shown that different mechanisms of the laser-induced magnetic switching of the magnetic nanolayers depend on the magnetic structure of the nanofilm on the intensity and polarization of the femtosecond laser pulse. At the irradiation of the films $Al_2O_3/Tb_{25}Co_5Fe_{70}/Al_2O_3$, $Al_2O_3/Tb_{19}Co_5Fe_{76}/Al_2O_3$, with one ferrimagnetic nanolayer with perpendicular anisotropy, the magnetic switching of this nanolayer takes place even in zero magnetic field so in the external magnetic field antiparallel to the initial magnetization of the nanolayer $Tb_{25}Co_5Fe_{70}$ and $Tb_{19}Co_5Fe_{76}$. Even more clearly the effect of reversal of the films shown at irradiation with circularly polarized femtosecond laser pulses. If the direction of the magnetic field of the inverse Faraday effect is opposite to the magnetization of the nanolayer $Tb_{25}Co_5Fe_{70}$ and $Tb_{19}Co_5Fe_{76}$ and its strength exceeds the coercive force, the magnetic switching occurs. For very high radiation intensity of the excitation femtosecond laser pulse, the delay time curve of photoelectric signal for the linearly polarized probe laser pulse passes through zero and becomes negative (Fig. 3). The magnetic switching of these nanolayer (transition via zero the photoelectric signal) occurs faster than $\tau<10$ ps. For the opposite circular polarization or linear polarization of femtosecond laser pulse, the magnetic switching of these nanolayer is not observed without an external magnetic field, even when the intensity of radiation becomes two times bigger.

It should be noted that the magnetization reversal occurs differently for the nanolayers $Tb_{25}Co_5Fe_{70}$ and $Tb_{19}Co_5Fe_{76}$. The nanolayer $Tb_{25}Co_5Fe_{70}$ remagnetized circulants action presents a polarized pulse earlier than the nanolayer $Tb_{19}Co_5Fe_{76}$. In addition, at the time of a powerful circularly polarized laser pulse, a slight increase of the photoelectric signal for the probe linearly polarized laser pulse, which suggests some effective amplification of the Faraday effect in the nanolayer $Tb_{25}Co_5Fe_{70}$ by powerful circularly polarized pulse. Remagnetization of the nanolayer $Tb_{25}Co_5Fe_{70}$ action presents a circularly polarized femtosecond pulses, which is the same as the reversal nanolayer $Tb_{19}Co_5Fe_{76}$. The observed difference in the reversal of nanolayers $Tb_{25}Co_5Fe_{70}$ and $Tb_{19}Co_5Fe_{76}$ may be caused by the different contributions of the sublattice magnetization of iron in the total magnetic moment of these nanolayers. In films $Tb_{25}Co_5Fe_{70}$ and $Tb_{19}Co_5Fe_{76}$ the total magnetic moment is directed toward the sublattice magnetization of iron, and in the film $Tb_{25}Co_5Fe_{70}$ it is directed in the direction of magnetization of the terbium sublattice. The magnetic field of the inverse Faraday effect is sent to the nanolayer $Tb_{19}Co_5Fe_{76}$ with its reversal of a circularly polarized laser pulse against the direction of magnetization of iron sublattice. In the nanolayer $Tb_{25}Co_5Fe_{70}$ similar reversing magnetic field is directed along the direction of magnetization of the sublattice of iron and directed against the direction of magnetization of the sublattice terbium. As a result of the laser-induced magnetic field the sublattice magnetization of iron is amplified. And because the magneto-optical effect in these nanolayers due to the interaction of light with the iron sublattice we have seen at the time of the circularly polarized femtosecond laser pulse in the nanolayer $Tb_{25}Co_5Fe_{70}$ of a slight increase of the Faraday effect in contrast to the nanolayer $Tb_{19}Co_5Fe_{76}$.

In the $Al_2O_3/Tb_{22}Co_5Fe_{73}/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}/Al_2O_3$ film at the set value of the external magnetic field and set value of intensity of radiation in a femtosecond laser pulse, we can get magnetization reversal of one nanolayer $Tb_{19}Co_5Fe_{76}$ with a minor coercive force or for a higher intensity of laser radiation of two magnetic nanolayers $Tb_{22}Co_5Fe_{73}$ and $Tb_{19}Co_5Fe_{76}$ simultaneously. Without the external magnetic field, magnetization reversal of the first magnetic nanolayer (relative to the irradiating laser pulse) occurs in the $Al_2O_3/Tb_{22}Co_5Fe_{73}/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}/Al_2O_3$ film in the same way as in the $Al_2O_3/Tb_{22}Co_5Fe_{73}/Al_2O_3$ or $Al_2O_3/Tb_{22}Co_5Fe_{73}/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}/Al_2O_3$ film. Magnetization reversal of the second magnetic nanolayer depends not only on the polarization of laser radiation, but also on the state of magnetization in both magnetic layers. In the film $Al_2O_3/Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\uparrow/Al_2O_3$ with parallel magnetized magnetic nanolayers, the laser-induced switching by circular polarization with femtosecond

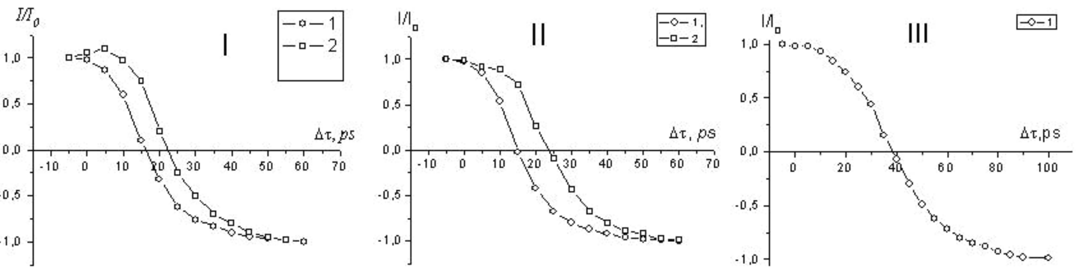

FIG. 3 THE DELAY TIME CURVE OF A PROBE LINEARLY POLARIZED FEMTOSECOND PULSES TRANSMITTED AND REFLECTED FROM A FILM: I –PROBE PULSE PASSES THROUGH FILM $AL_2O_3/TB_{19}CO_5FE_{76}/AL_2O_3$ (1) AND $AL_2O_3/TB_{25}CO_5FE_{70}/AL_2O_3$ (2), HIGH-POWER LASER PULSE IRRADIATES THESE FILMS IS CIRCULARLY POLARIZED; II –PROBE PULSE IS REFLECTED FROM THE NANOLAYER $TB_{19}CO_5FE_{76}$, HIGH-POWER LASER PULSE IRRADIATES THE FILM $AL_2O_3/TB_{22}CO_5FE_{73}\uparrow/PR_6O_{11}/TB_{19}CO_5FE_{76}\downarrow/AL_2O_3$ FROM THE NANOLAYER $TB_{22}CO_5FE_{73}$ AND HAS THE CIRCULAR POLARIZATION (1) AND LINEAR POLARIZATION (2); III –PROBE PULSE IS REFLECTED FROM THE NANOLAYER $CO_{30}FE_{70}$, THE HIGH-POWER LASER PULSE IRRADIATES THE FILM $AL_2O_3/CO_{80}FE_{20}\uparrow/PR_6O_{11}/\downarrow CO_{30}FE_{70}/AL_2O_3$ FROM THE NANOLAYER $CO_{80}FE_{20}$ AND HAS THE CIRCULAR POLARIZATION

laser pulse occurs without the external magnetic field in the result of the inverse Faraday effect. Depending on the laser radiation intensity magnetic switching can be realized only for one $Tb_{19}Co_5Fe_{76}$ nanolayer with a less coercive force, or simultaneous magnetic switching of two $Tb_{19}Co_5Fe_{76}$ and $Tb_{22}Co_5Fe_{73}$ nanolayers.

At magnetic switching of the nanolayer $Tb_{19}Co_5Fe_{76}$, the film passes from the state

$Al_2O_3/Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\uparrow/Al_2O_3$

with parallel magnetized magnetic nanolayers to the state $Al_2O_3/Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\downarrow/Al_2O_3$ with antiparallel magnetized nanolayers. At magnetic switching of two $Tb_{19}Co_5Fe_{76}$ and $Tb_{22}Co_5Fe_{73}$ nanolayers, the film passes from the state

$Al_2O_3/Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\uparrow/Al_2O_3$

with parallel magnetized magnetic nanolayers to the state $Al_2O_3/Tb_{22}Co_5Fe_{73}\downarrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\downarrow/Al_2O_3$ with parallel magnetized magnetic nanolayers, but their magnetization is directed to the opposite side. Temporal characteristics of such magnetic switching are close to dynamic behavior of the magnetic switching in the film $Al_2O_3/Tb_{22}Co_5Fe_{73}/Al_2O_3$ or $Al_2O_3/Tb_{25}Co_5Fe_{70}/Al_2O_3$ differing only in a power-level of the laser radiation.

According to the irradiation of the film $Al_2O_3/Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\downarrow/Al_2O_3$ by the nanolayer $Tb_{22}Co_5Fe_{73}$, we get the output reversal of this nanolayer without external magnetic field not only for the circular but for linear polarization with femtosecond laser pulses (Fig. 3-II). As a result, the film passes from the state

$Al_2O_3/Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\downarrow/Al_2O_3$

to the state $Al_2O_3/Tb_{22}Co_5Fe_{73}\downarrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\downarrow/Al_2O_3$. At the radiation of the film

$Al_2O_3/Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\downarrow/Al_2O_3$

from the side of the nanolayer $Tb_{19}Co_5Fe_{76}$ linearly polarized femtosecond pulses, we could not get a reversal of the output nanolayer $Tb_{22}Co_5Fe_{73}$ without external magnetic field. The dynamics of the laser-induced magnetic switching in the film $Al_2O_3/Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\downarrow/Al_2O_3$ under the circularly polarized femtosecond laser pulses from the side of the nanolayer $Tb_{22}Co_5Fe_{73}$ is similar to the case of the laser radiation from the side of the nanolayer $Tb_{19}Co_5Fe_{76}$ differing only by a laser power.

The results of the investigations of the films$Al_2O_3/Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\downarrow/Al_2O_3$with antiparallel nanolayer magnetizations show that a new physical mechanism of magnetic switching occurs in them. That mechanism is related to laser-induced spin current caused by a photon pressure. The laser-induced injection of spin-polarized electron from the nanolayer $Tb_{22}Co_5Fe_{73}$ through the tunnel barrier results in the nonequilibrium magnetic field $\overrightarrow{H_i} = \overrightarrow{H_e} + \overrightarrow{H_s}$. The self-field of the electric current H_e is directed to the film plane and the field of the total spin moment of injecting electrons is perpendicular to the film plane H_s. Our films are characterized by a large perpendicular anisotropy. Therefore, the effect of the magnetic field H_e on magnetic switching of the nanolayers is minimal. The conducted estimation of the field size shows that a spin current can result in magnetic switching of the nanolayer $Tb_{19}Co_5Fe_{76}$. The results of experimental researches of magnetic switching of the film

$Al_2O_3/Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}\downarrow/Al_2O_3$

at its radiation by femtosecond laser pulses certify this conclusion well.

At the irradiation of the films $Al_2O_3/Co_{30}Fe_{70}/Al_2O_3$ with one ferromagnetic nanolayer with the small

angular dispersion ($\Delta\alpha \approx 3^0$) of planar single-axis magnetic anisotropy, the magnetic switching of nanolayer takes place only in an external magnetic field, which is directed opposite to the magnetization of the magnetic nanolayer $Co_{30}Fe_{70}$. In the film $Al_2O_3/Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\downarrow Co_{30}Fe_{70}/Al_2O_3$with antiparallel magnetizations of the nanolayers, it is possible to get the magnetic switching of nanolayer $Co_{30}Fe_{70}$ without magnetic field. Such magnetic switching of nanolayer $Co_{30}Fe_{70}$ can be received only at the film $Al_2O_3/Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\downarrow Co_{30}Fe_{70}/Al_2O_3$ irradiation femtosecond laser pulses from the nanolayer $Co_{80}Fe_{20}$. For very high radiation intensity of the circularly or linearly polarized femtosecond laser pulses, the delay time curve for the reflected linearly polarized probe laser pulse passes through zero and becomes negative (Fig. 3-III). The magnetic switching of these nanolayer occurs faster than τ=30-40 ps.

The results of these investigation has shownthat the laser-induced switching can be realized not only for the case of perpendicular but also uniaxial planar magnetic anisotropy of the magnetic nanolayers. The magnetic switching of the low-coercive nanolayer $Co_{30}Fe_{70}$ without the external magnetic field takes place under the action of the internal effective magnetic field $\overrightarrow{H_i} = \overrightarrow{H_e} + \overrightarrow{H_s}$ laser-induced spin current caused by a photon drag effect of femtosecond laser pulse. The magnetic nanolayers $Co_{80}Fe_{20}$ and $Co_{30}Fe_{70}$ have a planar single-axis magnetic anisotropy, therefore the self-field H_e of the electric current and the magnetic field H_s related to the total magnetic moment of the injection spins have the direction in the plane of nanolayer $Co_{30}Fe_{70}$. In this case, the value of the internal effective magnetic field is the sum of these two fields $H_i=k_sH_s+k_eHe$, where где k_s и k_e are constants.

The research of influence of femtosecond laser pulse on resistance of microcontacts $Tb_{19}Co_5Fe_{76}/Pr_6O_{11}/Tb_{22}Co_5Fe_{73}$ and $Co_{80}Fe_{20}/Pr_6O_{11}/Co_{30}Fe_{70}$ $Co_{80}Fe_{20}/Pr_6O_{11}/Co_{30}Fe_{70}$ at the absence of magnetic field has shown that at small intensity of laser radiation the resistance of microcontacts falls at the moment of action of laser pulse, but after finishing of the pulse it returns back to the practically initial value. At a large intensity of laser radiation, the resistance of these microcontacts changes after the end of the laser pulse and this change depends on the state of magnetization of magnetic layers, on the intensity, and even on the incidence direction of laser pulses on the contact.

As our research shown (Fig. 4), the magnetic reversal of one of the electrodes changes the relative resistance in the microcontacts values ΔR/R>0,1 at *T=300 K* and ΔR/R>0,5 at *T=80 K*, while in the microcontacts $Tb_{22}Co_5Fe_{73}/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}$ ΔR/R>0,5 at *T=300 K* and ΔR/R>1,4 at *T=80 K*. In the external magnetic field directed towards the magnetization of the low-coercitive nanolayer $Co_{30}Fe_{70}$, the resistance of the microcontacts $Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\uparrow Co_{30}Fe_{70}$ after a radiation a powerful laser pulse increases on the value ΔR. The resistance of the microcontacts $Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\downarrow Co_{30}Fe_{70}$with antiparallel magnetizations of the nanolayers after an irradiation in the same magnetic field decreases on the value ΔR_0.

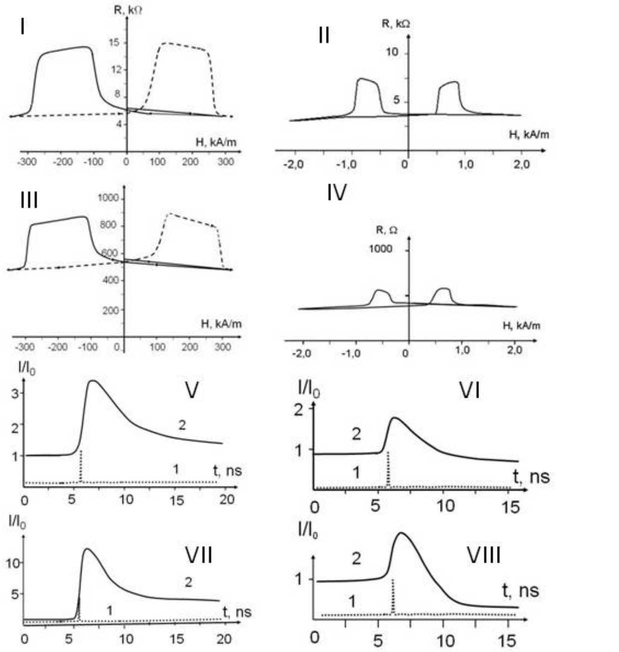

FIG. 4 THE CHANGE OF RESISTANCE OF TUNNEL CONTACT $TB_{22}CO_5FE_{73}/PR_6O_{11}/TB_{19}CO_5FE_{76}$ (I, III, V, VII1) AND $CO_{80}FE_{20}/PR_6O_{11}/CO_{30}FE_{70}$ (II, IV, VI, VIII) AT THEIR MAGNETIC SWITCHING OF AN EXTERNAL MAGNETIC FIELD (I-IV) AND UNDER THE INFLUENCE OF CIRCULARLY POLARIZED FEMTOSECOND LASER PULSE (V-VIII) AT T=300K (III, IV, V, VI) AND T=80K (I, II, VII,VIII).

The observed change of resistance of contacts $Co_{80}Fe_{20}/Pr_6O_{11}/Co_{30}Fe_{70}$ ΔR_0 on a value is close to the similar change of resistances that we observed during the magnetic switching of the same contacts only by the external magnetic field. In the microcontacts $Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\uparrow Co_{30}Fe_{70}$ with parallel magnetizations of the nanolayers in the absence of the magnetic field, it is impossible to get the change of resistance after radiation of a laser pulse. For such magnetic switching in the microcontact $Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\uparrow Co_{30}Fe_{70}$, it is necessary to select laser radiation intensity and external magnetic field carefully. In the microcontacts $Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\downarrow Co_{30}Fe_{70}$with antiparallel magnetizations of the nanolayers, it is possible to get the change of

resistance even in default of the magnetic field at a radiation of the nanosecond and picosecond pulses of lasers. The change of resistance in such microcontacts occurs only for the laser pulses directed from the side of the nanolayer $Co_{80}Fe_{20}$. For the laser pulses directed from the side of the nanolayer $Co_{30}Fe_{70}$, the change of resistance does not take place.

The laser-induced magnetic switching in the microcontacts $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\uparrow Tb_{19}Co_5Fe_{76}$ with parallel magnetizations of nanolayers is related to thermomagnetic and magneto-optic mechanism of the inverse Faraday effect at circularly polarized laser pulses. The laser-induced thermomagnetic switching of the low-coercive nanolayer $Tb_{19}Co_5Fe_{76}$ occurs when the external magnetic field is directed antiparallelly to the magnetization of this layer. Under femtosecond circularly polarized laser pulses, the change of resistance in the microcontact $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\uparrow Tb_{19}Co_5Fe_{76}$ without the external magnetic field occurs. The change of resistance in the microcontact $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$ was observed depending on a pulse polarization and the direction of the laser pulse on the microcontact. For the linearly polarized laser radiation directed from the side of the low-coercive nanolayer $Tb_{19}Co_5Fe_7$, the change of resistance without external magnetic field does not occur. For the same pulses directed from the side of the highly-coercive nanolayer $Tb_{22}Co_5Fe_{73}$, the resistance of reduction of the microcontact $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$ on the value ΔR without external magnetic field was observed. Such changes of resistance of the contacts after the irradiation of the lasers pulses are caused by magnetic switching of nanolayer $Tb_{19}Co_5Fe_{76}$ and the contact passes from the state $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$ with antiparallel magnetized nanolayers to the state $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\uparrow Tb_{19}Co_5Fe_{76}$ with parallel magnetized magnetic nanolayers. For the circular polarization of picosecond laser pulses which induce the magnetic field antiparallelly to the initial magnetization of the nanolayer $Tb_{19}Co_5Fe_{76}$, the resistance of microcontact $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$ decreases on the value ΔR without external magnetic field at the irradiation of this contact from any direction. Such changes of resistance of contacts $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$ after the irradiation with the circular polarization laser pulses are caused by magnetic switching nanolayer $Tb_{19}Co_5Fe_{76}$ of the laser-induced magnetic field (the inverse Faraday effect) and the contact passes from the state $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$ with antiparallel magnetized nanolayers to the state $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\uparrow Tb_{19}Co_5Fe_{76}$ with parallel magnetized magnetic nanolayers. At the opposite rotation of polarization plane of circular polarized femtosecond laser pulses, the change of resistance of microcontact $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$ takes place at a higher intensity of laser radiation. Such changes of resistance are connected with the transition of microcontacts from the state

$Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$

with antiparallel magnetized nanolayers to the state $Tb_{22}Co_5Fe_{73}\downarrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$ with parallel magnetized magnetic nanolayers in the direction of initial magnetized of nanolayer $Tb_{19}Co_5Fe_{76}$. The difference in intensities of radiation of the circular polarization picosecond laser pulses inducing a change conductivity of contacts $Tb_{22}Co_5Fe_{73}/Pr_6O_{11}/Tb_{19}Co_5Fe_{76}$ is explained by the fact that magnetic switching of the input magnetic nanolayer takes place only under the influence of the magnetic field of inverse Faraday effect H_F, while the magnetic switching of the output magnetic nanolayer is caused by the sum of this field H_F and field H_s related to the total magnetic moment of the injection spins.

Conclusions

The results of our experimental studies have shown that magnetic switching effects in the nanolayers under femtosecond laser pulses can be used for creation elements and systems of high-speed controlling of spin currents with the response time $\tau \leq 10^{-11} s$. For effective work of such optical controlled spin elements, it is necessary not only to develop a design and to choose a material with given characteristics but to set duration, intensity and polarization of controlling laser radiation.

Thus,in the tunnel microcontact $Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\uparrow Co_{30}Fe_{70}$ with parallel magnetized nanolayers which have the planar uniaxial anisotropy, the change of resistance under laser pulses is possible only under external magnetic field. In this case increment of the microcontact resistance occurs via laser-induced thermomagnetic switching of the low-coercive nanolayer $Co_{30}Fe_{70}$ and passage of the microcontact to the state $Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\downarrow Co_{30}Fe_{70}$. For the opposite magnetization of nanolayers in the given microcontact $Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\downarrow Co_{30}Fe_{70}$, the change of resistance can be realized in the low-resistance state $Co_{80}Fe_{20}\uparrow/Pr_6O_{11}/\uparrow Co_{30}Fe_{70}$ without external magnetic

field under laser pulse radiation from the side of the nanolayer $Co_{80}Fe_{20}$. In this case, magnetic switching of the nanolayer $Co_{30}Fe_{70}$ occurs under the action of internal nonequilibrium magnetic field as the result of laser-induced spin injection in this nanolayer from the nanolayer $Co_{80}Fe_{20}$ under the action of photon drag effect.

More effective control by spin current under nanosecond and picosecond laser pulses can be realized in the microcontact with perpendicular magnetic anisotropy of the nanolayers. Based on our study of tunnel microcontacts $Tb_{22}Co_5Fe_{73}$ / Pr_6O_{11}/ $Tb_{19}Co_5Fe_{76}$ with perpendicular magnetic anisotropy of magnetic nanolayers, it is possible to get the increase and decrease of conductivity without the external magnetic field. The increase of conductivity in this microcontacts related to the magnetic switching of nanolayer $Tb_{19}Co_5Fe_{76}$ and transition of microcontacts from the state $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$ with antiparallel magnetized nanolayers to the state

$$Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\uparrow Tb_{19}Co_5Fe_{76}$$

with parallel magnetized magnetic nanolayers is possible to get due to unpolarized radiation or linearly polarized radiation of nanosecond or picosecond laser pulses from the side of nanolayer $Tb_{22}Co_5Fe_{73}$ or due to the irradiation of the circular polarization picosecond laser pulses from any direction. For the decrease of conductivity related to the reverse transition of microcontacts from the state $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\uparrow Tb_{19}Co_5Fe_{76}$ with parallel magnetized nanolayers to the state $Tb_{22}Co_5Fe_{73}\uparrow/Pr_6O_{11}/\downarrow Tb_{19}Co_5Fe_{76}$ with antiparallel magnetized magnetic nanolayers without the external magnetic field, it is possible to get due to the irradiation of the circular polarization picosecond laser pulses. The magnetic switching of nanolayers with perpendicular magnetic anisotropy without the external magnetic field under the action of only laser radiation takes place under the influence of the magnetic field of the laser-injected spins or magnetic field created by the circular polarization picosecond laser pulses due to the reverse Faraday effect.

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The primary directions of experimental researches are spintronics, magnetic characteristics and spin transport in multilayered magnetic nanofilms, influence of laser radiation, the effect of laser radiation on the structure, optical, electrical and magnetic characteristics of materials, nonlinear optic, generation of terrahertz radiation. Achievements in the field of applied workings out include the research and product manager of product development: systems and magnetooptical data recording, laser driving systems and laser nanoprofilometer, systems for registration of the acoustic information and automated target systems for army training ground.